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BURST TEST FACILITY

Report No 88-133-K

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ABSTRACT

A major Burst Test Facility has been recently constructed at Research Division. The Burst Test Facility is capable of testing many full-scale power plant components such as pressure vessels and piping components under expected or postulated extreme operating conditions. This facility incorporates an above-ground heavily reinforced concrete containment structure which is capable of withstanding sudden energy releases of high pressure/high temperature gases or liquids, projectiles, noise and shock that may be encountered during component testing. This facility is unique because of: its ability to continuously supply hot pressurized water to the test component from the adjacent Pump Test Facility; its long rectangular shape (ideal for piping including full length reactor fuel channels with intact end fittings) and; its advanced "state-of-the-art" control, measurement, and process equipment.

job	file	date	report no.
21-547-550	825.22	October 7, 1988	88-133-K

Research Division
800 Kipling Avenue, Toronto, Ontario, Canada M8Z 5S4

MEMORANDUM

RECIPIENTS OF ATTACHED REPORT

September 9, 1988

Subject: Burst Test Facility (BTF)

FILE: 825.201(T)

Please find attached a copy of the report entitled "Burst Test Facility", OHRD Report No. 88-133 for your information. This report discusses in detail the Burst Test Facility design and testing capabilities as well as proposed work programs to utilize this facility.

The Burst Test Facility has just completed construction at the Research Division to meet the testing needs of our clients who require full-scale or scaled-down model testing of energized power plant components under representative station operating conditions. This divisional facility is an above-ground heavily reinforced concrete structure capable of containing the sudden energy release of high pressure gases or liquids, as well as projectiles, noise, and shock. This facility will be unique in the world because of its ability to continuously supply hot pressurized water or steam to the test component, its shape which is ideally suited for piping, and its state-of-the-art data acquisition and control systems.

If you should have any questions or comments regarding this report or future work programs that can be carried out in the Burst Test Facility, please contact either J.M Boag (X6090) or M.T. Flaman (X6998).

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Manager
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EXECUTIVE SUMMARY

BURST TEST FACILITY

J.M. Boag and M.T. Flaman
Applied Mechanics Section
Mechanical Research Department

The Burst Test Facility (located at the Research Division) is capable of testing full-scale power plant components such as pressure vessels and piping under actual or postulated extreme operating conditions. This facility incorporates an aboveground heavily reinforced concrete containment structure which is capable of withstanding the sudden energy releases of high pressure gases or liquids, projectiles, noise and shock that may be encountered during component testing. This facility is unique because of its ability to continuously supply hot pressurized water to the test component, its rectangular shape (ideal for piping) and its advanced "state-of-the-art" process, control, and measurement equipment.

The Burst Test Facility will be very useful in investigating concerns regarding structural integrity, efficiency, or fitness for purpose for existing components and for future design considerations. This facility will have a direct payback to Ontario Hydro by enabling equipment life to be extended, failure-prone equipment to be identified and certain plant operations to be performed more effectively. In addition, new technological advances in materials, design, and monitoring techniques can also be fully evaluated at this facility before implementation at the station.

This report describes and outlines the capabilities of the Burst Test Facility. Examples of Research programs to utilize this facility are also discussed.

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job	file	date	report no.
21-547-550	825.22	October 7, 1988	88-133-K

TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	BURST TEST FACILITY DESIGN SPECIFICATIONS	2
2.1	Overview	2
2.2	BTF Postulated Component Failure Conditions	2
3.0	BURST TEST FACILITY FEATURES	3
3.1	Burst Containment Room	3
3.2	Control Room/Mechanical Service Room	4
3.3	Hot Pressurized Water Supply	4
3.4	Steel Reaction Floor	4
3.5	Control, Measurement, and Process Equipment	5
4.0	ADVANTAGES OF FULL-SCALE COMPONENT/SCALED-DOWN MODEL TESTING	6
5.0	CONCLUSIONS	7
APPENDIX I	- Typical Work Programs	8 & 9
APPENDIX II	- BTF Process Test Conditions	10
DISTRIBUTION		last page

TABLE OF FIGURES

Figure		Page
1	Burst Test Facility	1
2	BTF Cutaway View	2
3	BTF - Plan View	4
4	BTF - Elevation View	4
5	Process Equipment Schematic	7

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To Dr. D. Mills
Director of Research

BURST TEST FACILITY

1.0 INTRODUCTION

The Burst Test Facility (as shown in Figure 1 & 2) has the capability to test power plant components such as pressure vessels and piping components under simulated operating conditions, eg, flow, pressure, vibration, applied forces/moments, and temperature. This facility will not only be used to determine the structural integrity of existing plant components, but is intended to be used in conjunction with many other OHRD programs investigating material behaviour, erosion/corrosion phenomena, thermal hydraulics mechanisms, etc. so that improvements in reliability, efficiency, and safety are achieved.

Typical examples of work programs to utilize this facility include pressure/calandria tube behaviour studies and primary heat transport pipe cracking studies to investigate leak rates and structural integrity. A comprehensive list of work programs to utilize this facility is given in Appendix I.

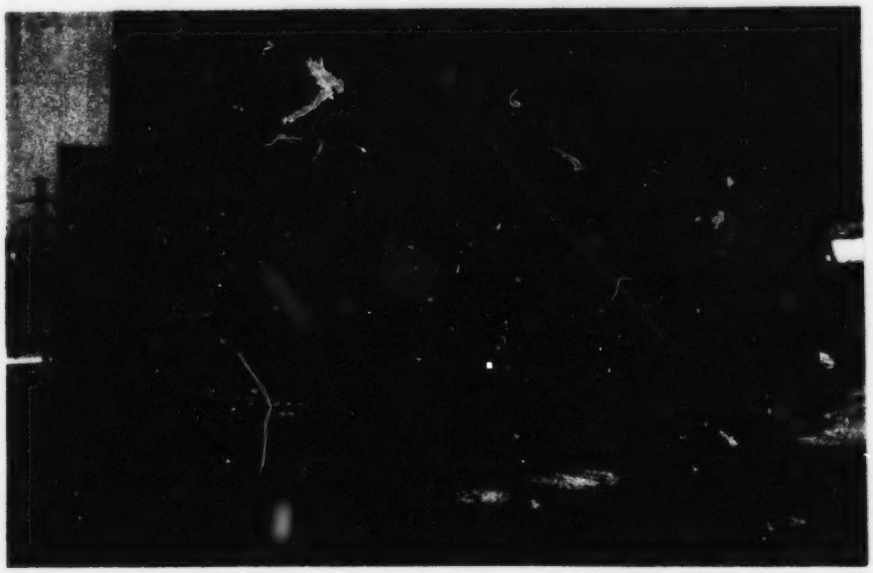

Figure 1 - Burst Test Facility

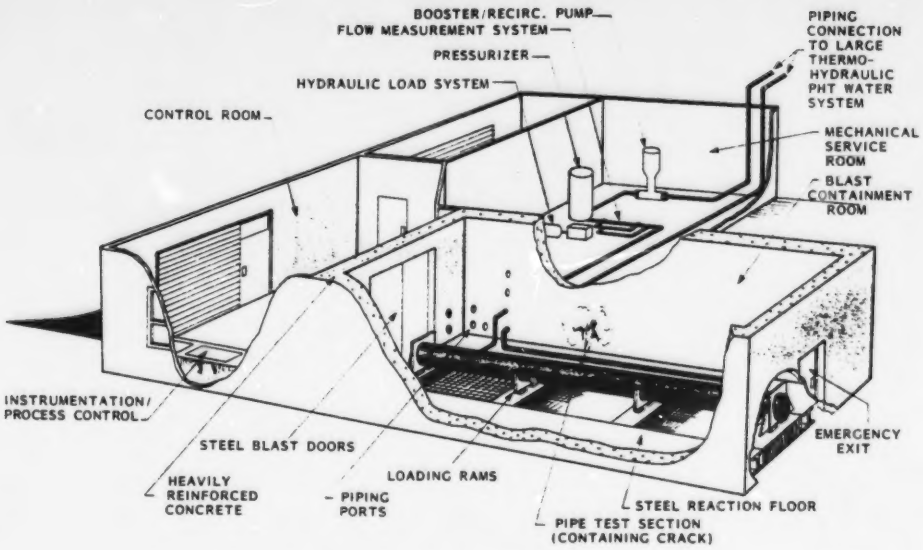

Figure 2 - BTF Cutaway View

2.0 BURST TEST FACILITY DESIGN SPECIFICATIONS

2.1 Overview

The Burst Test Facility has been designed to safely withstand burst or rupture involving sudden high energy releases. The facility is able to accommodate test requirements involving; high temperature, externally imposed forces and moments, vibrations, and high pressure steam and water.

The possible failure of a component under test may subject the BTF to the sudden release of high pressure gases (which must be exhausted) or liquids, high energy projectiles, noise and shock, as described below for these typical types of component tests.

2.2 BTF Postulated Component Failure Conditions

The design and qualification of the BTF was based upon the maximum sudden energy release that can be accommodated by the typical tests to be carried out which are described below.

a) The catastrophic brittle failure of a pressure tube with end fittings measuring 10 m long, 100 mm ID, and a 5 mm wall filled with water/steam at 350°C and 20 MPa pressure.

b) The unexpected failure of a pressurized and steam leaking steel Primary Heat Transport (PHT) pipe measuring 0.56 m diameter, 10 m long, 50 mm thick wall, filled with steel filler bars and water/steam at 350°C and 20 MPa pressure. (The volume of pressurized water would be approximately 1.23 m^3). The steam leak rate is 10 kg/sec for a through-wall crack.

c) The sudden rupture of a 1050 mm diameter, 70 mm thick wall steel pressure vessel containing steel filler bars and

water at 550°C pressurized at 35 MPa, and containing water/steam. (The volume of the pressurized water would be approximately 0.66 m^3).

d) The failure of a 610 mm diameter 50 mm thick steel disc rotating around its axis at 30,000 rpm.

3.0 BURST TEST FACILITY FEATURES

The BTF, shown in Figures 3 and 4, is an above-ground "self-contained" structure comprised of a Control Room, a Mechanical Service Room, and a Burst Containment Room (testing area).

3.1 Burst Containment Room

The Burst Containment Room is constructed of heavily reinforced concrete with the walls having a thickness of approximately 0.5 m. The inside Burst Containment Room dimensions are approximately 12 m long x 4 m wide x 4 m high. The Burst Containment Room has a hinged steel blast door between the Burst Containment Room and the Control Room. The steel blast door is approximately 2.1 m wide x 2.5 m high.

A fundamental feature of this facility is its long (horizontal) shape. This facility has been designed specifically to test representative lengths of pipes and full length pressure tubes (including intact end fittings with feeder pipe attachments). The facility does have the ability to test relatively large, high energy, pressure vessels as well.

To exhaust heat and steam generated during a test or from the sudden failure of a pressurized component, steel exhaust pipes are connected through the concrete containment roof to the outside. These exhaust pipes have been embedded into the walls and extend approximately 3 m above the outside roof level.

3.2 Control Room/Mechanical Service Room

An integral part of the BTF is the Control Room (approximately 4 m long x 4 m wide) which will be used for the control and monitoring of tests. An insulated utility door has been installed at the end of the Control Room so that large test components can be transferred from the loading area and moved through the Control Room into the Burst Containment Room. Cable ports (approximately 150 mm diameter) exist between the Control Room/Burst Containment Room walls for routing of instrumentation cable.

A Mechanical Service Room (approximately 6.8 m long x 6.2 m wide) is attached to the north end of the BTF. The Mechanical Service Room houses the process pressurizing system pump,

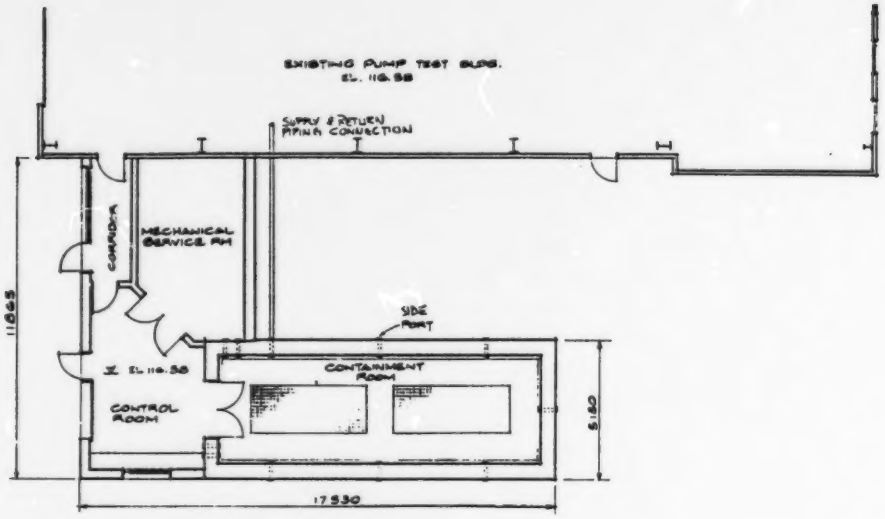

Figure 3 - BTF - Plan View

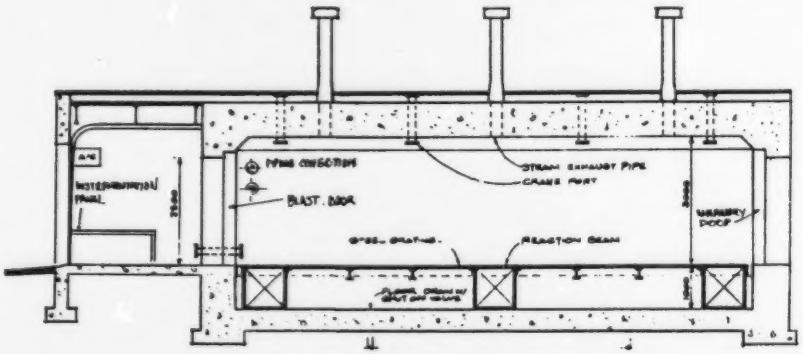

Figure 4 - BTF Elevation View

component heating equipment, and a pressure vessel reservoir. Ports (approximately 300 mm diameter) exist in the Mechanical Service Room for routing of piping into the Burst Containment Room.

3.3 Hot Pressurized Water Supply

A unique and very important feature of the Burst Test Facility is the availability of a large supply of hot pressurized water for testing purposes (i.e., PHT operating conditions up to 13.8 MPa and up to 300°C). This is supplied by a direct piping connection to an existing large thermal hydraulic loop in the adjacent Pump Test Building. Presently, approximately 26,500 L

of water at simulated CANDU PHT temperature, pressure, and chemistry conditions can be supplied on a once through basis to the BTF. This capability would enable investigations to be undertaken on cracked and leaking components. For example, a leak rate of 0.5 kg/sec through a cracked pipe could be sustained for more than 15 hours. In addition, the PTC has a make-up capability of 1000 litres/hour under continuous flow conditions.

Studies have shown that a booster pump and supplemental heating can enhance the water conditions to simulate PWR, BWR, and certain thermal plant operating conditions under continuous flow conditions.

3.4 Steel Reaction Floor

An integral matrix of robust steel reaction beams exists at the bottom of the burst containment room. (The top surface of these beams, are at ground level and, along with steel grating, provide a working floor.) The reaction floor has two modes of operation:

i) Reaction floor for testing components loaded on top of the floor, and

ii) Horizontal loading frame (up to 5,000,000 lbs in tension or compression) for testing components inside the reaction floor (with the steel gratings removed).

3.5 Control, Measurement, and Process Equipment

The control equipment is fully computer controlled and is used to control both the measurement and process equipment. The measurement equipment consists of high-speed and general data acquisition systems capable of measuring stress, strain, pressure, temperature, crack growth, flow, forces and moments.

The process equipment will include a piping connection from the adjacent Pump Test Building thermo-hydraulic loop to the BTF recirculation/booster pumps, pressurizers, turbine flow meters, automatic shut-off valves, pressure relief valves, etc. A typical schematic of the process equipment is shown in Figure 4 and Appendix II describes typical process test conditions. The piping material is a SA106 Grade B ferritic steel (i.e. representative nuclear piping).

All process equipment (excluding pumps) have been designed to a working pressure and temperature of 2,000 psi and 350°C, respectively. The process parameters of pressure and temperature can be controlled to within ±50 psi and ±5°C respectively, for most testing configurations.

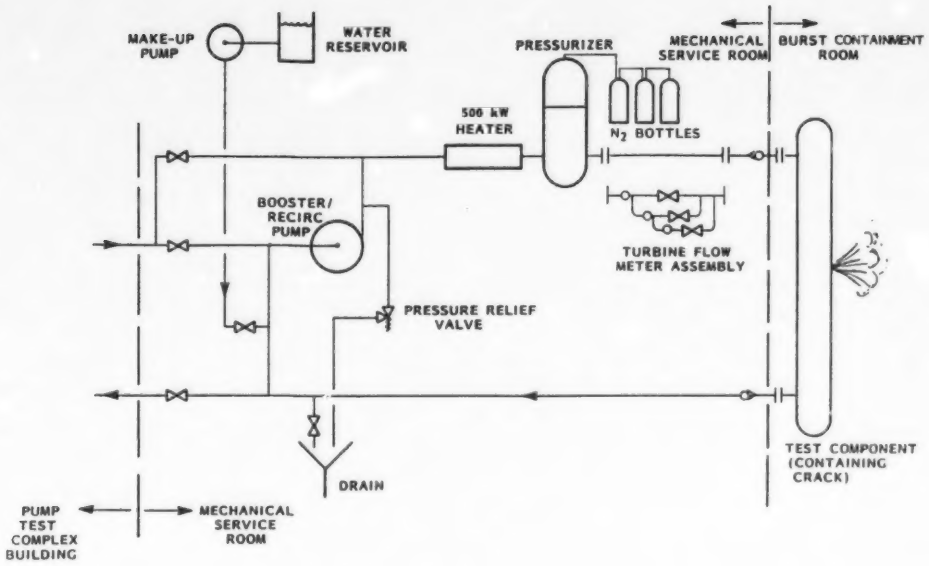

Figure 5 - Process Equipment Schematic

For those components that are fundamental to the continuing operation and safety of our power stations, an additional capability is the full-scale verification testing of such components in a qualified test facility.

4.0 ADVANTAGES OF FULL-SCALE COMPONENT/SCALED-DOWN MODEL TESTING

Advantages of full-scale testing or scaled-down model testing as compared to specimen testing for power plant components include:

1. Simulating various expected and extreme operating conditions (regarding pressure, load, temperature, etc) at both normal, and accelerated rates in component life studies (eg. plant life extension) to evaluate the margins of conservatism in design, operation, and inspection.

2. Performing certain physical testing under conditions which cannot be accurately simulated by mathematical modelling or specimen testing, (ie, piping leak rate tests, loss of coolant accident (LOCA), sudden component rupture, etc).

3. Obtaining data on the behaviour of actual power plant components which would enable the validation and possible improvement of the approximations and assumptions which were used in the initial design.

5.0 CONCLUSIONS

1. The Burst Test Facility is a "state-of-the-art" unique testing facility and is capable of providing full-scale testing for Ontario Hydro and external companies upon request.

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APPENDIX I

TYPICAL WORK PROGRAMS

The following typical work programs and types of testing can be readily performed in the Burst Test Facility.

1. Darlington "Leak Before Break" PHT Piping Studies - To validate analytical leak rate models and investigate the integrity of PHT pipes containing part-through and through-wall cracks.

2. Pressure/Calandria Tube Studies - To study the dynamic response of the calandria tube as a result of a pressure tube rupture.

3. Ice-Plugging of Nuclear Piping Components - To determine the structural behaviour of nuclear piping components while undergoing an ice-plugging maintenance procedure.

4. Pipe Whip Studies - Investigate potential damage and hazards caused by a sudden rupture of critical nuclear piping components.

5. Two-Shift Mode of Operation for Thermal Power Plants - To determine the rate of structural degradation of critical thermal plant components in an accelerated laboratory simulation of two-shifting.

6. Fracture Mechanics/Fatigue Studies - To determine the residual life, structural integrity, and behaviour of actual power plant components with known flaws or defects.

7. General Structural Testing (Including Scaled-Down Model Testing) - Determine structural behaviour of power plant components under various loading conditions, ie, thermal, mechanical, vibration, etc, for design and operation improvements.

8. On-line Component Monitoring - Documentation and development of an on-line structural integrity monitoring system for nuclear power plant components.

9. Plant Life Extension - To determine the residual life remaining in critical power plant components in order to extend their life expectancy.

10. Power Manoeuvring for Nuclear Power Plants - To determine the structural behaviour of nuclear components under these operating conditions.

11. Fuel Channel "Cascading" Failure Mode - To investigate the effects on adjacent fuel channels as a result of a single fuel channel rupture.

12. Rupture of Feeder Pipes - To examine the resulting mechanical and thermal-hydraulic consequences within the reactor.

13. External Testing Requirements (EPRI, CEA, etc.)

It should be noted that this list is not complete and other types of structural testing may arise according to future needs and requirements.

APPENDIX II

BTF PROCESS TEST CONDITIONS

The major process equipment loop operates under the following minimum operating test conditions listed below.

a) CANDU Component Structural Testing

Hot pressurized water can continuously circulate through the booster/recirc pumps, heaters, and test component. The hot pressurized water flows through the recirc pump which operates with relatively low differential pressure across the pump due to system hydraulic losses. Typical test components would be a fueled DNGS type fuel channel and sections of PHT piping. External forces, moments, or vibrations, if required, can be imposed independently to the component. The component can be left unattended for long periods of time, e.g., nights, weekends, etc.

p = 1700 psi (Pressure of entire piping system)
T = 320°C
Q = 30 kg/sec (i.e. typical flow through a fuel channel)
Test Time = 30 days

b) Test Condition #2 - CANDU Component Leak Rate Testing

Hot pressurized water from the Pump Test Complex (PTC) (at 1700 psi and 300°C) can be supplied to the process piping, heaters, and turbine flow meters and "leaked" into the BTF Containment Area.

p = 1700 psi
T = 300°C
Crack Leak Rates = 0.01 kg/sec - 10 kg/sec
Test Time* = 1 hour - 24 hours

c) Test Condition #3 - PWR Component Leak Rate Testing

Hot pressurized water from the Pump Test Complex can be supplied at 1700 psi and 300°C to the process equipment booster pump, heaters and turbine flow meters and "leaked" into the BTF Containment Area.

p = 2600 psi (1700 psi supplied plus 900 psi boost pressure)
T = 350°C (300°C supplied by PTC plus 50°C boost temperature)
Crack Leak Rates = 0.01 kg/sec - 2.5 kg/sec
Test Time* = 1 hour - 24 hours

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* Length of time that the above leak rates can be sustained will be dependant on the PTC reservoirs and water make-up capability. i.e., 26,500 litres.